Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia - Social and Behavioral Sciences 51 (2012) 1080 – 1086
Procedia Social and Behavioral Sciences

ARTSEDU 2012

Examination of earthquake resistant design in the education of architecture

Asena Soyluk [a] *, Zeynep Yeşim Harmankaya [b]

[a] *Dr., Gazi University, Maltepe Campus, Ankara, 06570, Turkey*
[b] *M.Sc., Gazi University, Maltepe Campus, Ankara, 06570, Turkey*

Abstract

This study has been carried out to identify the knowledge of students about the irregularity of the structures and to assess the effect of power point presentation provided. It was conducted on the last year undergraduate students at Gazi University Department of Architecture. The questionnaire form designed by the researcher to collect data, was used as a pre-test to know about the students' earthquake resistant design. Then the students were provided with earthquake resistant design training. Following the training, the questionnaire was employed as a post-test to identify the effect of the training and the difference between the pre-test and post-test was determined.

Selection and/or peer review under responsibility of Prof. Dr. Ayse Çakır Ilhan.

Keywords: Irregular Buildings, Structure Knowledge, Earthquake Resistant Design, Architectural education, Power-point presentation

1. Introduction

Earthquake is one of the major problems for Turkey because of its location on the Alp-Himalayas Fault, which is one of the most active earthquake areas on the world. Being very close (about 5-30 km) to the surface, the earthquakes that occur especially on the North Anatolian fault are very dangerous [Ministry of Public Works and Settlement Government of Republic of Turkey, 2011]. In the last 58 years, 58 202 people were killed, 122 096 were injured due to earthquakes in Turkey. Moreover nearly 411 465 buildings were collapsed or heavily damaged. In brief, almost 1003 people die and 7 094 buildings collapse per year in Turkey [Turkish Republic Disaster and Emergency Management Precedency, Earthquake Department, 2012].

The investigations of damage which have occurred in past earthquakes have clarified the causes of earthquake damage in structures. There may be listed as follows:

a. Undesirable geometric configuration
b. Inadequate lateral stiffness
c. Flaws in detailing

According to experiences from past earthquakes of Turkey, the collapses or damages of buildings were directly or indirectly related to the architectural design. Since the irregularity of a building is one of the main causes of heavy damages, there has been a title called "Irregular Buildings" in Turkish earthquake code since 1998 [Specification for Structures to be Built in Disaster Areas, 1998]. Under this title, some types of buildings are

* Corresponding Author; Asena Soyluk. Tel.: +90-312-582-3657
E-mail address: asenad@gazi.edu.tr

1877-0428 © 2012 Published by Elsevier Ltd. Selection and/or peer review under responsibility of Prof. Ayşe Çakır İlhan
Open access under CC BY-NC-ND license. doi:10.1016/j.sbspro.2012.08.291

defined as irregular, and architects are advised to avoid these kinds of irregular configuration designs. However this section in the Turkish earthquake regulation is not clearly understood by the architecture students.

Architects who work on seismic regions should give adequate consideration to 'earthquake' as a design criterion when it is compared with the more ordinary ones such as customer demands, function, aesthetics and environmental factors. Under the influence of the uncommon and impressive designs of the new structures which are rising in non-seismic regions, the architectural students in Turkey could not completely recognize the importance of the earthquake's devastating impact and resistance of the structures to the lateral seismic loads. Such earthquake - resistance criteria should be instructed and emphasized in the architectural design education in earthquake zone located countries like Turkey.

2. Turkish Earthquake Code

In Turkey, there is an earthquake code that is used to determine the behavior and the earthquake resistance of the buildings [Specification for Structures to be Built in Disaster Areas, 2007]. At the beginning of this code it is mentioned about earthquake resistant buildings under the chapter of "Analysis Requirements for Earthquake Resistant Buildings". This chapter is generally dedicated to architectural design and it is most important section for architects (Harmankaya & Soyluk, 2012).

The main section of the part that addresses the most to the architectural audience is the "Definition of İrregular Buildings". Irregular buildings are defined in this part as "*buildings whose design and construction should be avoided because of their unfavourable seismic behavior*". In this section, various types of geometric arrangements and structural behavior patterns in plans and elevations of buildings are identified as irregularities in terms of seismic design. As seen from Figure 1, these irregularities, first divided into two groups. The first group is about irregularities seen in plan called "A-type of irregularities" and second one is concerned with irregularities in elevation called "B-type of irregularities". Then, irregularities in plan and in elevation are further subdivided into three groups. But, the important point in the identification of such concepts is that all irregularities are defined as solely mathematical formulas.

Figure 1. Irregularities according to 2007 Turkish Earthquake Code [Specification for Structures to be Built in Disaster Areas, 2007].

A – *IRREGULARITIES IN PLAN*	B – *IRREGULARITIES IN ELEVATION*
A1 – Torsional Irregularity : The case where *Torsional Irregularity Factor* η_{bi}, which is defined for any of the two orthogonal earthquake directions as the ratio of the maximum storey drift at any storey to the average storey drift at the same storey in the same direction, is greater than **1.2**. $[\eta_{bi} = (\Delta_i)_{max} / (\Delta_i)_{ort} > 1.2]$ *Storey drifts shall be calculated in accordance with* **2.7**, *by Considering the effects of* ± *%5 additional eccentricities.*	**B1 – Interstorey Strength Irregularity (*Weak Storey*) :** In reinforced concrete buildings, the case where in each of the Orthogonal earthquake directions, *Strength Irregularity Factor* η_{ci} which is defined as the ratio of the *effective shear area* of any storey to the *effective shear area* of the storey immediately above, is less than **0.80**. $[\eta_{ci} = (\Sigma A_e)_i / (\Sigma A_e)_{i+1} < 0.80]$ *Definition of effective shear area in any storey* : $\Sigma A_e = \Sigma A_w + \Sigma A_g + 0.15\, \Sigma A_k$
A2 – Floor Discontinuities : In any floor ; **I** - The case where the total area of the openings including those of stairs and elevator shafts exceeds 1/3 of the gross floor area, **II** – The cases where local floor openings make it difficult the safe transfer of seismic loads to vertical structural elements, **III** – The cases of abrupt reductions in the in-plane stiffness and strength of floors.	**B2 – Interstorey Stiffness Irregularity (*Soft Storey*) :** The case where in each of the two orthogonal earthquake directions, *Stiffness Irregularity Factor* η_{ki} , which is defined as the ratio of the average storey drift at any storey to the average storey drift at the storey immediately above, is greater than **1.5**. $[\eta_{ki} = (\Delta_i)_{ort} / (\Delta_{i+1})_{ort} > 1.5]$ *Storey drifts shall be calculated in accordance with* **2.7**, *by considering the effects of* ± *%5 additional eccentricities.*
A3 – Projections in Plan : The cases where projections beyond the re-entrant corners in both of the two principal directions in plan exceed the total plan dimensions of the building in the respective directions by more than **20%**.	**B3 - Discontinuity of Vertical Structural Elements :** The cases where vertical structural elements (columns or structural walls) are removed at some stories and supported by beams or gusseted columns underneath, or the structural walls of upper stories are supported by columns or beams underneath

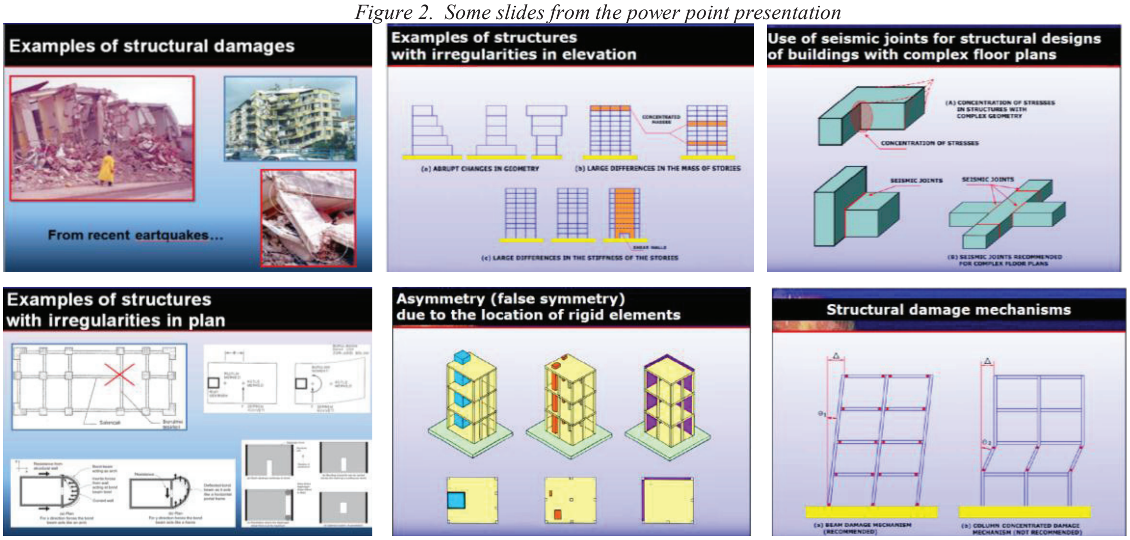
The codes main advice for the designers is to avoid these irregularities altogether if possible. However, the code also defines the structural calculation assumptions and precautions to be taken in case such irregularities exist in the building. It should be noted here that because the earthquake code is not prepared with an architect-friendly approach, especially the irregularity types created by geometric arrangements such as projections in mass and gallery openings are widely misunderstood and often undeservedly objected by architects. The earthquake code does not forbid the existence of such architectural elements but simply calls for attention to the consequences of using these elements in terms of the seismic behavior of the building [Ozmen&Unay , 2008]. The authors believe that an adequate verbal definition supported by the suitable graphic material will be more meaningful for an architect than a set of formulas.

3. The Power Point Presentation

Architectural education is a multidisciplinary which includes many various branches of science and art. The main goal of architecture is to construct the most convenient artificial environment for mankind. Architectural education process is based on examining and producing new solutions. The aim of theoretical and practical lessons is increase the quality of work produced according to design. Although there has been much discussion over different methods to teach architecture students, lectures are not likely to stop being used. To emphasize particular points, many lectures use written material presented on a chalkboard, whiteboard, or by transparencies on an overhead projector [Simons, 2004]. In the last 10 years, another method of presenting visual information with lectures has gained prominence: projecting information directly from a computer onto a screen (e.g., PowerPoint presentations) [Nicholsan, 2002].

In this study, authors wanted to test the training of Turkish Earthquake Code whether using PowerPoint lectures that are supported by graphics, pictures and visual effects would be liked more and would lead to better grades than using lectures supported by mathematical operations (Fig.2). This study conducted on the 60 final year undergraduate students at Gazi University Department of Architecture in Ankara.

Figure 2. Some slides from the power point presentation



The questionnaire form designed by the present researcher to collect data, was used as a pre-test to know about the students, structure knowledge and earthquake resistant design. Then the students were provided with earthquake resistant design training. Following the training, the questionnaire was employed as a post-test to identify the effect of the training and the difference between the pre-test and post-test was determined.

4. The Foresight of the Architecture students in Earthquake Resistant Design education process

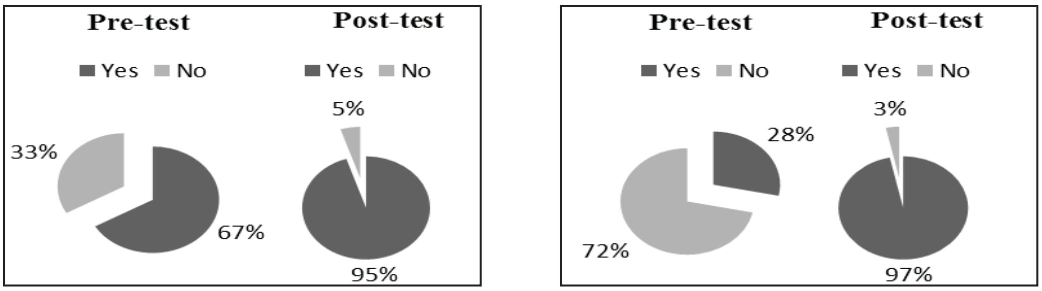
The architecture occupation is a dynamic and open to innovations and varying continuously. Therefore its education criteria are discussed all over the world. Especially in Turkey, having the high risks of earthquake danger as a whole, sensitiveness about architecture and engineering education is important as well as continual development of earthquake regulations, earthquake resistant structure design and production. In architecture departments, it is necessary to put the emphasize on consideration of earthquake resistant structures and interdisciplinary study skills, taking architecture design into consideration, structure frame must be associated with earthquake resistant as well as having the aesthetics point of view. Utilizing the training technology about earthquake resistant design studies has led to successful conclusions on students.

According to the scientific researches, the architectural design mistakes are stated as the major factors for the earthquake demolitions and damages. In the research, this over and over scientifically proved fact has been come into question. Before the power point presentation about the issue, only 33 % of the students suppose that defects in the architectural design affects the earthquake demolitions. But, after the presentation, this ratio has been raised up to the 95%. (Fig. 3a).

In relation with this issue, the ratio of the students thinking that seismic design initiates with the architectural design is 28% in pre-test. After the training, only 3% of the students don't think that architectural design is the main point of seismic design (Fig. 3b). These questions have clearly stated the necessity of the students' awareness about seismic design.

Figure 3.(a) Do you think architectural design faults are the participant of the results?, (b) Do you agree with that seismic design initiates with the architectural design?

(a) *(b)*

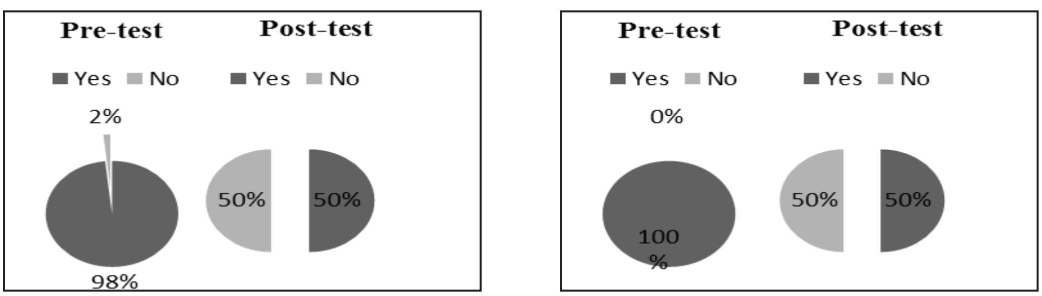


By putting emphasis on the issue, the ratio of the students who thinks earthquake design is more related with the engineers was 98 % before the training. Then, 50 % of the students find it necessary to follow the seismic design rules (Fig.4a).

The number of students who express the responsibility of seismic resistance of buildings belongs to engineers is the highest ratio of 100%. After the presentation, the ratio of the students who see the responsibility to be equal is 50% (Fig. 4b). However, Slak and Kilar (2003) point out that "no static analysis could assure a good dissipation of energy and favourable distribution of damage in irregular buildings, such as structures with large asymmetry or soft storeys . According to the percentage of distributions, architectural students should compare and differ their roles and responsibilities of architects and structural engineers about the issue.

Figure 4.(a) Do you agree with that 'Earthquake' is an expertise, which is more related with the engineers?, (b) Do you agree with that structural engineers' responsibility is much more than architects' in seismic design of buildings?

(a) *(b)*

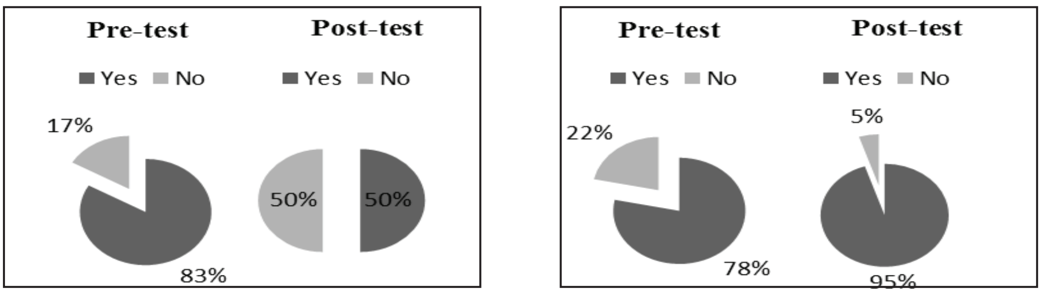


83% of the students pointed out that engineers could transform every architectural design into earthquake resistant ones with the static calculations and alternative solutions. That only the esthetic is necessary to design the structures in current architectural education and that how students are skilled at earthquake resistant design cannot be measured through these parameters cause students to start this designing education reluctantly and unconsciously. After the presentation the ratio of the students who see the applications to be done with engineers is 50% (Fig.5a).

It is essential to discuss the necessity of consideration of earthquake and architecture based issues related to seismic design as a design criterion. The present attitude of architects towards the issue should be questioned. In relation with this issue, 22 % of the architects in the sample group agree before the training and 95 % of them agree that 'earthquake' must be considered as a design criterion for architects when they are designing on seismic zones after the training (Fig 5b).

Figure 5.(a) Do you agree with that structural engineers are able to transform every building, no matter how they are designed by architects, into earthquake resistant ones with the static calculations and alternative solutions?, (b) Do you agree with that earthquake must be considered as a design criterion for architects when they are designing on seismic zones?

(a) *(b)*

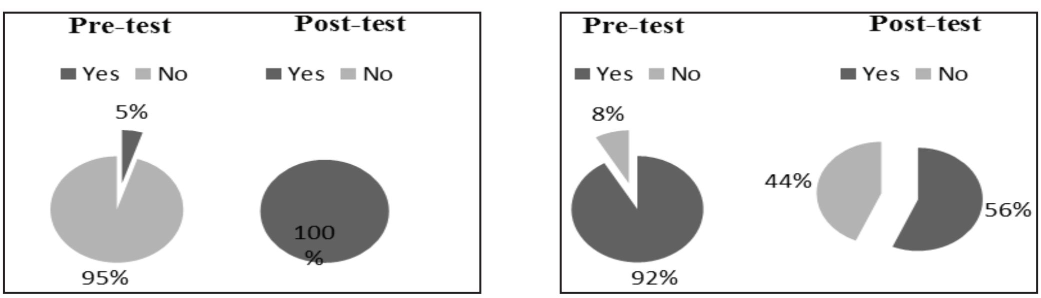


In terms of the question, which is about whether architectural students have professional knowledge about the "Specification for Structures to be Built in Disaster Areas, 2007" , only 5% of the students have some idea about the irregularities part of 2007 Turkish Earthquake Code (Fig 6a). The survey conducted to final year architecture students. However, it is surprising that these students didn't investigate this code until the end of undergraduate education. Following the presentation, all of them passed over the issue with visual materials.

92% of the students find architecture-based seismic design issues are obstacles for architectural creativity and freedom before the training. The majority of the students find the regulation unnecessary for architects. Even if graphics in the regulation access opportunities improved, seismic regulations are one of the necessities for architectural designs (Fig.6b).

Figure 6.(a) Have you ever examined the irregularities part of 2007 Turkish Earthquake Code, which is more related to architects?, (b) Do you agree with that Architecture-based seismic design issues are obstacles for architectural creativity and freedom

(a) *(b)*



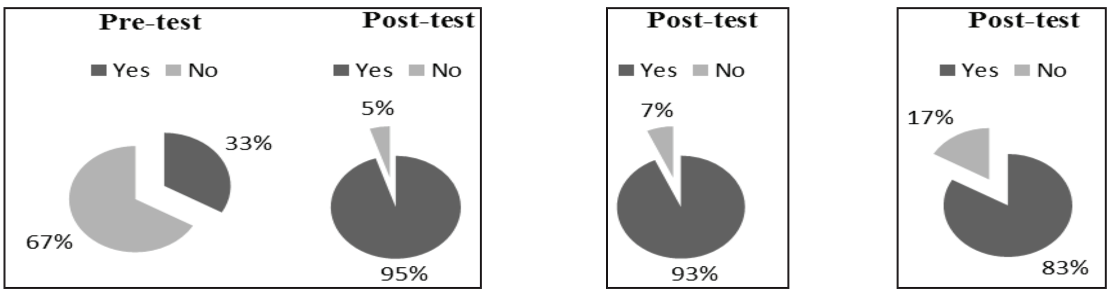
Arnold (1989) points out that "for a given ground motion, the major determinant of the total inertial force in the building is the building mass". The form and the size of the building with the choice of materials establish the mass. As configuration mostly determines how seismic forces are distributed throughout the building, it is an important consideration from seismic point of view. It also influences the relative magnitude of seismic forces. A variety of configuration can be designed for any architectural program, each of which affects the distribution of seismic forces differently. For a better seismic performance, 'regular' configuration, which means the optimum or ideal configuration in dealing with lateral forces (such as earthquake forces), should be designed. In the light of this information 33% of the students thought form and geometry effect seismic performance. After the training this ratio increases to 5% (Fig. 7a).

The students were tested in order to find out whether the irregularities showed with graphics and pictures is thought to be more clear than the mathematical formulas or not. Most of the students affirmed the power poınt presentatıon positively. 93% of the students pointed out that important thing is not mathematical formulas, but the visual materials(Fig. 7b).

The students were asked whether this presentation could beneficial for the other architecture departments, and 83% of the students confirmed that it would be useful for the other architectural students(Fig. 7c).

Figure 7.(a) Does Form and geometry in architectural design affect seismic performance of the buildings?, (b) Observing the irregularities visually compared to mathematical formulas is more clear and consistent or not ?, (c) Could be this presentation beneficial for the other architecture departments ?

(a) *(b)* *(c)*



5. Conclusions

Because earthquake is the reality of the geographic structure of Turkey, Turkish people must learn how to deal with it. It is necessary to make not only architects but also everyone on the country have the consciousness of being aware that Turkish people have been living on a country being prone to earthquakes and they have been living with earthquake risk for many years. In this respect, education is one of the most important concerns in order to form consciousness and awareness.

Students of architecture, as being the future designers of the buildings, are to be informed about the architecture-based seismic design issues. According to the analyses' distributions, most of the respondents are aware of the importance of the architectural design on seismic performance of buildings and their roles and responsibilities in seismic design after the power-point presentation. It must be known that laws and regulations are systems of rules developed by government or society to control social or business relationships. Before laws and regulations, there should be adequate education. Then, mission of laws and regulations can be accomplished. Past experiences have been showed that earthquake codes did not provide the enhanced of building performances. This study revealed that the issue of earthquake resistant design and architectural education should be considered more carefully and illustratively.

Authors have also noted that in students' opinion, the power-point presentation makes the topic interesting and increases the visual impact of the subject. They also pointed out its unique advantages including presentation of 3D images, pictures, sequence of images.

References

Ministry of Public Works and Settlement Government of Republic of Turkey's web site provides many links to seismic codes, seismic maps and earthquake Researches. (http://sismo.deprem.gov.tr/VERITABANI/hasar.php)

Harmankaya,Z.Y. & Soyluk, A., (2012). Architectural design of irregular buildings in Turkey, International Journal of Civil & Environmental Engineering (IJCEE-IJENS) 12(1), 42-48.Retrieved from http://www.ijens.org/Vol_12_I_01/125001-9494-IJCEE-IJENS.pdf

Özmen, C. & Ünay, A.İ. (2007). Commonly encountered seismic design faults due to the architectural design of residential buildings in Turkey. *Building and Environment*, 42 (3), 1406-1416. Retrieved from http://www.sciencedirect.com/science/article/pii/S0360132305005123

Naeim, F., (Arnold, C.), (1989). *The Seismic Design Handbook*. New York; Van Nostrand Reinhold

Nicholson, D.T. (2002), Lecture Delivery Using MS PowerPoint: Staff and Student Perspectives at MMU, Learning and Teaching in Action, 2002-(2), 1-12. Retrieved from http://www.celt.mmu.ac.uk/ltia/issue2/nicholson.shtml

Turkish Republic Disaster and Emergency Management Precedency, Earthquake Department's web site provides many links to Earthquake information (http://www.deprem.gov.tr/depremnedir/depremnedir.htm)

Simons, T. (2011, September 15), Does PowerPoint make you stupid?. Presentations magazine. Retrieved from http://www.sociablemedia.com/PDF/press_presentations_magazine_03_01_04.pdf

Slak, T. & Kilar, V., "Initial Conceptual Design of Earthquake Resistant R/C and Masonry Buildings According to Eurocode 8", University of Ljubljana, Faculty of Architecture, Slovenia, 2003 (On-line) Available: http://www.curee.org/architecture/bibliographies.html

Specification for Structures to be Built in Disaster Areas (1998). *Chapter 6 irregular buildings* (Amended on: July1998). Ministry of Public Works and Settlement Government of Republic of Turkey.

Specification for Structures to be Built in Disaster Areas (2007). *Chapter 6 irregular buildings (*Amended on: March 2007*)* Ministry of Public Works and Settlement Government of Republic of Turkey.